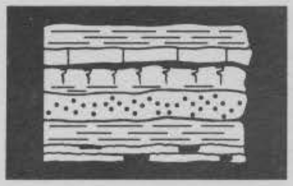
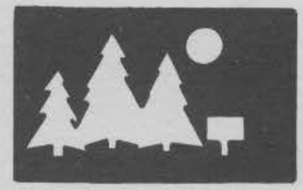
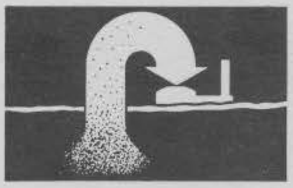
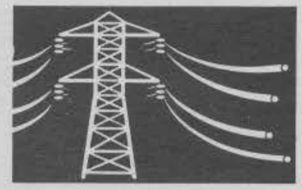
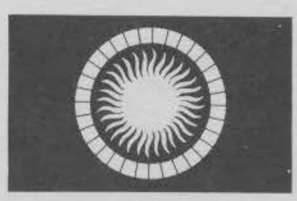
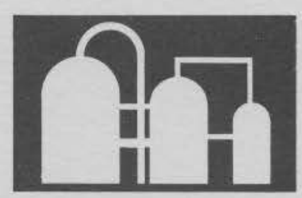




THE ROLE OF COAL IN MISSOURI

MISSOURI DEPT. OF NATURAL RESOURCES
Division of Geology and Land Survey, Rolla, MO 65401

THE ROLE OF COAL IN MISSOURI

SEPTEMBER 1979

Prepared By

MISSOURI DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGY AND LAND SURVEY

MISSOURI DEPARTMENT OF NATURAL RESOURCES
P.O. Box 176 Jefferson City, Missouri 65102 (314) 751-4422

Honorable Joseph P. Teasdale
Governor
State Capitol
Jefferson City, Missouri 65101

Dear Governor Teasdale:

This report is submitted in response to your request for an assessment of the potential for coal development in Missouri.

Missouri's current annual production of nearly 7 million tons could potentially be increased fourfold to 29 million tons. As a practical matter, though, economic factors will determine whether or not this production capability will be realized. With the enactment of the Missouri Clean Air and Land Reclamation Acts, the state can proceed with the mining and use of Missouri coal in an environmentally sound manner.

I can assure you that our department, with a cooperative effort between our Divisions of Energy, Environmental Quality, and Geology and Land Survey, will work aggressively to increase the use of Missouri coal.

It is our opinion that the most important actions for state government to take will be increased research to improve our knowledge of Missouri coals, as well as development of improved technologies to use coal in an environmentally sound manner.

Sincerely,

DEPARTMENT OF NATURAL RESOURCES

Fred A. Lafser

Fred A. Lafser
Director

FAL:rjk

Joseph P. Teasdale Governor
Fred A. Lafser Director

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EXECUTIVE SUMMARY

Missouri coal is a $60 million per year industry which employs more than 1,600 persons and produces over 6 million tons of coal from 19 strip mines, operated by 14 producers.

- *Measured recoverable reserves of strippable coal* are estimated at 633 million tons — enough to supply the state's coal needs for many years at the present rate of consumption. Further drilling and exploration would better define the limits of strippable coal deposits within the state and should be encouraged because it would add to the known reserves of strippable coal. Reserves, recoverable by underground mining, could also be increased by drilling and exploration designed to fill gaps in current knowledge of coal bed extent, thickness, and depth. (See pages 7 and 8).

- *A potential exists* for increasing Missouri's annual coal production by more than 22 million tons.

- The presence of coal reserves does not necessarily mean that these reserves are available for mining. Large blocks of coal land are becoming more difficult to assemble. *Nonavailability of land* is one of the factors which limits the measured reserves which can be mined economically. (See page 9).

- *Only 29 percent* of the 23 million tons of coal consumed annually within the state is Missouri coal. Consumption of coal for electrical generation is expected to increase by more than 5 million tons per year by 1985. *Production will need to be increased* if the state's coal industry continues to provide 29 percent of the coal consumed.

- In addition to the increased tonnage of coal expected to be needed by utilities for electric power generation, *an increase in demand* could also develop for industrial use through direct combustion as certain industries are forced to convert from natural gas to other fuels. (See page 5).

- *Coal gasification projects now in the planning stage* would require several million tons of Missouri coal annually if one or more of them were to become operational. Projects in planning are the *Missouri Energy Center* at Palmyra, Mo. (proposed by Northeast Missouri Power Cooperative and Farmland Industries, Inc.) and *Combined Cycle/Coal Gasification* plants in Sullivan and Howard Counties, Mo. (proposed by the Consumer Energy Corporation). Each project proposes gasification of Missouri coal for electric power generation along with utilization of the low Btu gas for other purposes. At present progress with the Missouri Energy Center is reported to be delayed.

- *Conversion of coal to high Btu gas,* suitable for long-distance transportation by pipeline, is considered uneconomical unless operations are on a large scale. Such a plant should not be undertaken in Missouri unless a large block of uncommitted coal reserves can be assembled. (See page 17).

- *Experimental in-situ coal gasification facilities* are presently being operated in Wyoming and West Virginia. Missouri's thin coal seams would be

ideal for a third facility if the ongoing experiments are successful. (See page 19).

- *Recovery of methane from deep coal seams* is being examined in other coal fields and may be found to be technically and economically feasible. Evaluation of this possibility in Missouri will require drilling and sampling of deep coal beds. (See page 19).

- *Missouri coals generally contain from 4 to 5 percent sulfur* which must be removed in either the pre-combustion, combustion, or post-combustion phases if these coals are to be burned in an environmentally acceptable manner. The economics of using Missouri coals, including removal of sulfur by beneficiation and/or stack gas cleaning, must be compared with the economics of using imported low sulfur coals. Missouri coal markets could be expanded appreciably if the economics become more favorable. (See page 11).

- *Sulfur removal in the pre-combustion stage* involves commercial coal beneficiation techniques including washing, gravity separation, and flotation. Sulfur removal is also possible by techniques such as chemical cleaning or solvent refining. Solvent refining is approaching demonstration-plant status and offers an opportunity to produce a clean burning fuel from high sulfur, high ash coal. (See pages 13 and 19).

- *Fluidized bed boiler technology* may permit the efficient and economical burning of medium and high sulfur coals and meet the EPA clean air criteria without the use of a stack gas clean-up system. In this process, coal and limestone are fed to a fluidized bed boiler where the sulfur oxides react with the limestone and lime to form calcium sulfate which is carried out with the fly ash and collected in a low-pressure cyclone dust collector or electrostatic precipitator. (See page 13).

- *Lime and limestone wet scrubbers* are post-combustion desulfurization processes in which the SO_2 in the gases is converted to calcium sulfates which are waste materials and require disposal. Over 25 limestone scrubbing systems have been installed in the United States. The La Cygne, Kansas plant, owned and operated jointly by the Kansas Gas and Electric and Kansas City Power and Light Companies, is equipped with "scrubbers" and utilizes coal from western Missouri and adjacent areas in Kansas. Springfield City Utilities' Southwest No. 1 also utilizes Missouri coal and is equipped with "scrubbers." Three additional Missouri units now under construction or in the planning stages will be equipped with lime or limestone scrubbers. They are Associated Electric's Thomas Hill No. 3, Springfield City Utilities' Southwest No. 2, and Sikeston's Municipal Utilities No. 1. The solid waste disposal problem and the energy required to produce fine-grained limestone or lime for the process and the additional energy needed for wet scrubbing must be considered in the economics of this process. *Other post-combustion processes* such as the IFP ammonical brine process or the Bureau of Mines citrate process produce a salable sulfur product. Post-combustion processes can usually be added to existing boilers, though this is more expensive than designing new facilities with post-

combustion processes. (See page 14).

All coals contain trace amounts of a variety of elements. In some cases these offer a potential for by-product recovery while in other cases a potential air or water pollution problem may be indicated. Information is presently being accumulated on the character of trace elements in Missouri coals and their disposition during mining and combustion. (See pages 11 and 12).

- *Alternatives to coal* have been reduced in their relative importance, so near and intermediate-term *roles of coal in Missouri are better defined now* than in the past. Continued acceleration in the use of coal mined in the Midwest as well as in the West is considered certain. Consequences in Missouri include:

  Some large and several small to medium sized generating plants, designed to burn Midwest high sulfur coal, are likely to be built in Missouri; they will utilize FGD "scrubber" equipment to meet air quality standards.*Research* on the occurrence and final disposition of trace and minor elements should be carried out so as to identify potential hazardous relationships as well as opportunities for recovery of trace elements from wastes. Additionally, specific research is needed to determine options in the disposal of the waste material generated by large coal-burning facilities.

  Direct combustion of Missouri coal (its most efficient use) should be encouraged. Development of the *fluidized-bed combustor* is seen as advanced technology for direct use of Missouri and other high sulfur Midwest coals in power generators. This system offers many advantages over conventional boiler systems using FGD systems for sulfur clean-up. The study of Missouri coal characteristics as they relate to consumption in fluidized-bed combustors is an area of research and development that would be helpful in aiding transition from conventional boiler systems using FGD to fluidized-bed boilers.

  In the same context, *investigation of the suitability of individual Missouri limestones and dolomitic limestones* for use in fluidized-bed combustors is needed. Finally, the disposition of waste material and of trace elements may require specific investigation beyond that required for traditional combustion as noted above.

  Substitution of coal (through direct combustion) for natural gas or oil in Missouri's industrial sector is an important but inadequately defined opportunity. Reducing the requirements (already subjected to curtailment in many instances) for high priority fuels and for expanding the use of coal should be investigated in detail. *The nonutility industrial sector* offers a near-term opportunity for expanding the use of coal, and represents one of the applications of fluidized-bed combustion.

  The potential for *application of the Solvent Refined Coal (SRC) process* to Missouri coal is important and needs specific investigation with large sample testing in an existing pilot plant. This process offers an opportunity to use even the state's poorest coals. (See page 19).

Some Missouri coal will ultimately be utilized through various conversion technologies that will convert coal to clean-burning gaseous and liquid fuels, but the projected timing will vary with economic factors and national policy. These fuels can, in turn, be used in many direct applications as well as for feedstock in the chemical industry. Specific characterization of Missouri coals, along with geologic assessment of reserves by area and seam, will be essential to economic and technological analysis of their suitability for specific conversion processes.

RESEARCH RECOMMENDATIONS

Support is recommended for the following research on uses of Missouri coal and development of the state's coal mining industry. Research items (listed in the order they are discussed in the report) are broken down into short term and long term applications where practical.

RESEARCH AREAS

Production and Comsumption (Section I)

1. Survey of the potential for substituting coal for natural gas as a fuel in industry.

Coal Resources (Section II)

Short Term:

1. Determine that part of the state's coal resource base that constitutes a recoverable resource under present and near-term economic and environmental constraints.

Long Term:

1. Study the feasibility of underground mining of thin coal seams in Missouri.

Characteristics of Missouri Coals (Section III)

Physical and Chemical Characteristics:

1. Determine organic and inorganic chemical characteristics of Missouri coal.
2. Study petrographic characterization of selected coal beds.

Trace Elements:

1. Analyze representative samples from all active and potential mining areas in the state.
2. Study trace elements considered to be environmental hazards.
3. Determine the concentrations of potentially hazardous elements in bottom ash and fly ash and investigate disposal methods.
4. Determine the fate of potentially hazardous elements dispersed into the atmosphere or hydrosphere through combustion, beneficiation, or conversion processes.
5. Investigate the potential for commercial recovery of metals from ash and beneficiation products.

Direct Combustion of Missouri Coals (Section IV)

1. Determine the feasibility of upgrading Missouri coals through beneficiation.
   a. Make washability studies to establish the degree of sulfur removal obtainable by heavy media separation, jigging, tabling, cycloning, or other gravity separation methods.
   b. Determine whether known separation processes can be applied to fine-ground Missouri coal to improve sulfur elimination. Froth flotation, dry magnetic separation, dry chemical processing, and wet high-intensity magnetic separation are processes to be examined.
2. Make evaluation studies to determine the benefits (or lack of benefits) of desulfurization of Missouri coals by combining beneficiation/flue gas cleaning processes.

Gasification and Conversion (Section V)

Short Term:

1. Demonstrate the economic feasibility of low to intermediate Btu gasification plants for industrials or utilities use or for producing petrochemical feedstocks.
2. Study the feasibility of producing solvent refined coal from Missouri coal.
3. Sample and test coals to determine their amenability to various conversion processes.
4. Investigate the possibility of utilizing Fluidized Bed Combustion processes for the direct combustion of high-sulfur Missouri coal.
5. Establish the mineralogical classification of Missouri coals and determine whether the correlations prevailing between mineralogical type and combustion efficiency, and ease of gasification or liquefaction for coals in other coal regions also applies to Missouri coal.

Long Term:

1. Demonstrate the practicality of in-situ gasification of deeply buried coal seams.
2. Demonstrate the practicality of recovery of methane from deeply buried coal seams.

INTRODUCTION

Recent events in our country's efforts to cope with its deepening energy problems, culminating in President Carter's message of July 15, 1979, focus attention upon the role of coal in meeting our energy needs; nationally, regionally, and on the state and local level. On July 19, in a statement responding to President Carter's speech, Missouri's Governor Joseph Teasdale stressed the importance of a higher degree of energy self-sufficiency for Missouri, and encouraged development of coal and technology for coal gasification and liquefaction.

Missouri's coal resources are capable of supplying significantly greater amounts of energy in the form of electricity, industrial fuel, and synthetic fuels. This report highlights the potential of Missouri's coal for meeting a greater percentage of the State's energy needs and suggests specific direction for coal development in the state. Principal constraints to increased coal utilization, including the current market as well as environmental factors, are presented. Finally, recognizing that major research efforts will be required if optimum utilization of Missouri coal is to take place, selected areas of research are identified.

This report represents a revised and expanded version of an interim report prepared in 1977 by the then-active Missouri Coal Research and Development Committee, which included representatives from coal mining, electric utilities, academic, and governmental sectors.

Charles E. Robertson, chief of the Mineral Fuels Section, Division of Geology and Land Survey, developed and refined successive drafts and coordinated final preparation of this report.

Table 1

1978 MISSOURI COAL PRODUCTION

Operator	Employees	Tonnage
Bills Coal Co.	168	264,542
Coal Creek Fuel Co.	4	15,362
Ellis Coal Co.	(Closed)	2,611
Howard Coal Co.	8	34,231
International Energy Co.	26	158,142
Midwestern Mining Reclamation	21	47,976
Mid-West Resources	9	2,000
Mexico Coal Co.	7	25,719
Missouri Mining Co.	216	888,173
NEMO Coal Co.	67	244,084
Peabody Coal Co. (Bee-Veer)	227	477,488
Peabody Coal Co. (Tebo Mine)	172	282,281
Peabody Coal Co. (Prairie Hill)	129	519,389
Peabody Coal Co. (Power Mine)	210	920,988
Pittsburg & Midway Coal Co. (Empire)	73	406,985
Pittsburg & Midway Coal Co. (Midway)	168	1,097,452
Mr. Jim Reeves	0	864
Universal Coal & Energy	107	454,712
Merle Wharton	5	741
Totals	**1,617**	**5,843,740**

Data from Inspection Sect., Mining, Mo. Dept. of Labor & Ind. Relations, Div. of Labor Standards

SECTION I

COAL PRODUCTION AND CONSUMPTION

PRODUCTION

A total of 5,843,740 short tons of coal was produced in 1978 by fourteen operators (table 1). This is a drop of 783,200 tons from the record 1977 production which followed a 10-year upward trend that started in 1957 with 2.5 million tons of coal being produced. Production had increased 250 percent in that 10-year period (fig. 1). The 1978 production decline was a result of a strike by the United Mine Workers. More than 330 million tons of coal have been produced in Missouri since 1840.

COAL MINE EMPLOYMENT

Employment in the coal industry was more than 1,600 in 1978 versus 1,298 in 1974, and 1,400 in 1976 according to the Division of Employment Security, Missouri Department of Labor and Industrial Relations. This upward trend in employment can be expected to continue.

CONSUMPTION

Nearly 23 million tons of coal were consumed in Missouri in 1976, the last year for which complete data are available. Nearly 21 million tons were consumed by public utilities for the generation of electricity, the remainder being consumed by coke and gas plants, retail dealers and for other uses.

Missouri coal production accounted for about 30% of the utility coal. The remainder was shipped from other states, mostly from Illinois but with a significant and increasing amount from Wyoming.

U.S. DOE projections indicate an increase in utility coal consumption to 25.7 million tons by 1986 (an increase of nearly 5 million tons over 1976). By the year 2000 DOE projects a further increase of 6.4 million tons over 1986 consumption and by the year 2020 an increase of 27.9 million tons over 1986 consumption.

It is apparent then from the previous figures that there should be a growing demand for utility coal in Missouri in the coming decades.

There is also a potential need for increased coal consumption to be satisfied in the industrial sector. Nine percent of Missouri's coal production is used in the industrial sector where coal is consumed by the stone, glass, clay and other industries. The minerals industry uses coal in manufacturing cement and it has a potential application in the refractories industry and for the production of chemical feedstocks.

The pattern of retail trade in coal has changed in Missouri markedly since World War II. In 1946, 3,600,000 tons of coal were sold by retail dealers as compared to only 103,000 tons in 1975. However, the importance of coal as a source of space heating in rural areas should not be discounted. A relatively small amount is used for this now but its importance could increase as prices for other fuels rise. The recent appearance on the market of furnaces capable of burning both coal and wood are indicative of an increasing use of coal for domestic space heating.

Currently, Missouri produces aproximately a third of the utilities coal that it consumes. Use of Missouri coal by utilities could increase during the next

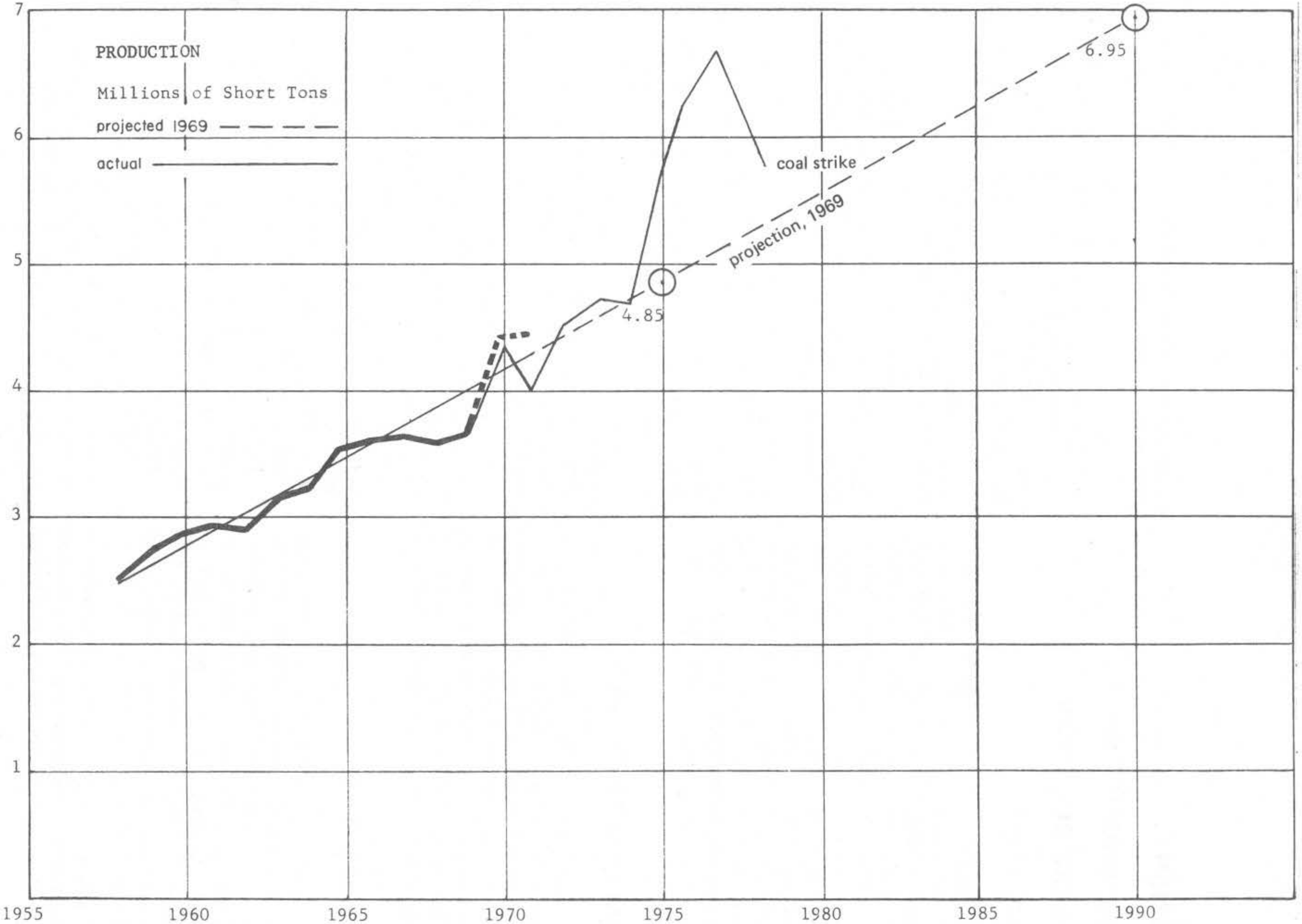

Figure 1

Missouri coal production (millions of short tons) for the period 1957 through 1978 and forecasts. Source: Spec. Publ. No. 1, *Missouri Minerals,* 1969, Mo. Geol. Survey & Water Resources.

decade, particularly if the economics of flue gas desulfurization improves. However, high production costs, high sulfur content, and air quality standards limit the potential for use of Missouri coal in new utilities plants. The question of how much of the projected new utilities coal requirement can be met by Missouri coal remains unanswered.

IMPACT OF WESTERN COAL

The railroad and the mining industry are demonstrating that they can mine and transport Western coal for great distances competitively. Coal slurry pipelines may provide even cheaper transportation. The relative ease of mining Western coal and the enormous resources available make it particularly attractive to mining companies.

New Source Performance Standards recently announced by the EPA may improve the position of Missouri coal in the utilities market. These standards would essentially require the scrubbing of all coal regardless of the initial sulfur content. Because scrubbers would be required on facilities burning low-sulfur coal as well as on those burning high-sulfur coal, the cost advantage that western coal now has over Missouri coal would be reduced in new facilities.

POTENTIAL FOR INCREASED INDUSTRIAL USE OF MISSOURI COAL

Increased industrial use of coal is important as a means of replacing other fuels such as gas or oil and increasing use of Missouri coal. Nine percent of Missouri's coal consumption is by the industrial sector for steam raising, process uses, and feedstocks. Over 50 percent of this is consumed by the stone, glass, and clay industries. The second largest user of industrial coal is the chemical and allied products industry which accounts for 14 percent of the state's annual consumption. Other industries relying on industrial coal are the food and kindred products industry (5 percent) and the transportation equipment industry (3 percent).

A survey by the Missouri Energy Agency in 1975 determined that of 400 firms that were interruptible users of natural gas, 23 could substitute coal for natural gas or other petroleum products. Fifty percent had physical limitations that prevented coal substitutions and 13 percent could not afford the cost of conversion.

The minerals industry utilizes coal in manufacturing cement and it has a potential application in the refractories industry. Based on the amount of clinker produced, there is probably a potential for the use of nearly one million tons of coal in the cement industry. Potential also exists for converting coal to low Btu gas for the direct reduction of iron ore and for using pulverized coal feed for traveling-grate pellet plants.

The potential for coal-oil slurries in industrial boiler applications also deserves consideration as a means of extending the use of coal. The use of coal-oil mixtures provides one method of replacing oil with coal to fuel industrial boilers. Since the mixture is a liquid and could easily be used in conventional oil-burning equipment, lower investments would be required for retrofitting. Other advantages of the coal-oil mixture would be less premature system replacement, and shortened plant closings due to restructuring plants. Because Missouri coal is high in sulfur content, a coal-oil mixture using Missouri coal would not meet New Source Performance Standards unless the sulfur content of the coal was first reduced substantially by advanced beneficiation techniques.

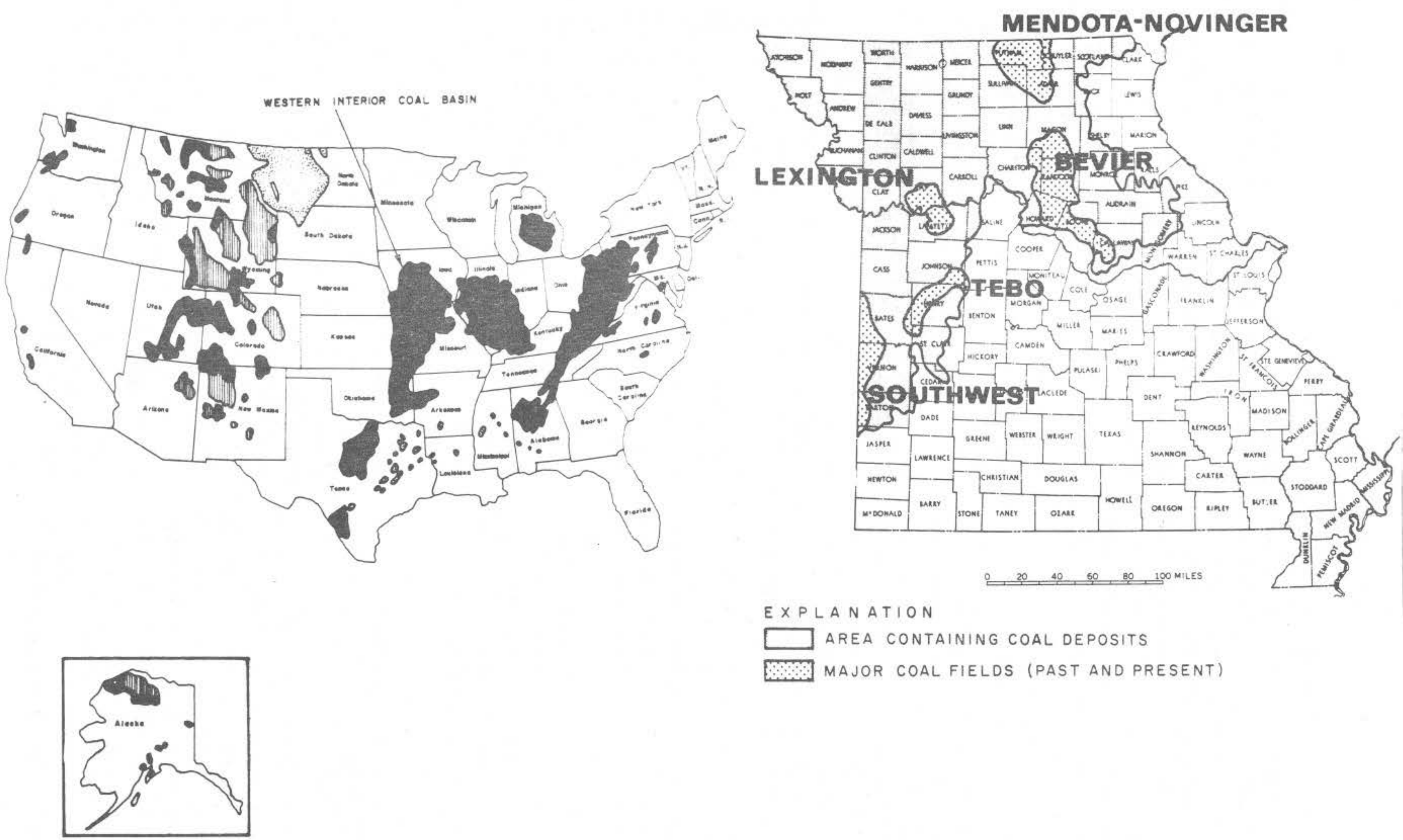

Figure 2

Coal and lignite fields in the United States (left); coal deposits in Missouri and major coal fields (past and present). Source: RI 54, *Mineable Coal Reserves of Missouri,* 1973, Mo. Geol. Survey & Water Resources.

SECTION II

COAL RESOURCES

OCCURRENCE

The coal fields of Missouri are an integral part of the Western Interior Coal Basin, which also includes parts of Iowa, Kansas, Oklahoma, and Arkansas (fig. 2a). This large coal region contains a significant portion of the total coal resource base of the United States.

Figure 2b shows the distribution of coal deposits in Missouri and the location of important coal fields. The Lexington Field is inactive at present.

Geologically, Missouri's coal seams occur in strata of Pennsylvanian age as do most of the coal seams of the midwestern and eastern United States. More than 30 coal seams have been identified in Missouri. Only 14 are of sufficient thickness and areal extent to be considered sources of potentially mineable coal.

MINING METHODS

Missouri's coal seams are relatively thin making extraction per ton more expensive than that in regions with substantially thicker coal seams. This is somewhat counterbalanced by comparatively favorable overburden thickness and the good lateral continuity of some seams. The latter conditions are favorable for strip mining which is an economical method both from the standpoint of cost and of coal recovery. From 75 to 90 percent of the coal seam is usually recovered by stripping, while underground methods generally recover only about 50 percent; much of the remainder is rendered unrecoverable and is therefore wasted. In addition, some coal seams which could not be recovered at all by underground mining are recoverable by stripping methods.

In the early years of coal mining in Missouri most mining was done by underground methods. However, underground mining in Missouri began to decline steadily in the 1930's in favor of strip mining. By the mid-1960's underground mining had all but ceased due to the competition from stripping and loss of markets. At present there are no underground coal mines operating in Missouri.

COAL RESERVE ESTIMATES

IN MISSOURI

The problem of preparing meaningful estimates of reserves of any mineral commodity is compounded by a lack of uniformity in methods. State and Federal agencies invariably use different definitions and methodology than do mining companies. Even more frustrating is the lack of uniformity among government agencies or again among private companies. This is not necessarily the result of incompetence or lack of understanding, but rather due to the complex nature of the factors affecting reserve estimates and the differing perspectives of the estimators.

Historically, reserves of ores and other minerals have often been divided into three classes by mining interests. These are: developed, undeveloped, and potential. Developed reserves are those which have been sampled adequately by drifting or drilling with sample spacing sufficient to positively insure the volume of recoverable ore. Applied to coal, this means that in areas where the continuity of the coal bed is known to be consistent, a spacing of coal sampling of approximately 600 foot centers is considered sufficient, while areas having

Table 2

REMAINING MEASURED RECOVERABLE COAL RESERVES OF MISSOURI
(by county)

July 31, 1976 (Million Tons)

County	Strippable Reserves	Subsurface Reserves	Total Measured Reserves	County	Strippable Reserves	Subsurface Reserves	Total Measured Reserves
Adair	6.0	31.8	37.8	Lafayette	7.7	3.4	11.1
Audrain	13.5	1.9	15.4	Linn	–	11.5	11.5
Barton	39.5	–	39.5	Livingston	0.5	–	0.5
Bates	63.4	42.2	105.6	Macon	53.4	9.5	62.9
Boone	57.2	14.1	71.3	Mercer	–	20.6	20.6
Callaway	20.0	8.9	28.9	Monroe	3.4	–	3.4
Cass	–	1.2	1.2	Montgomery	1.0	–	1.0
Cedar	7.1	–	7.1	Pettis	0.4	–	0.4
Chariton	12.4	19.7	32.1	Putnam	31.5	7.0	38.5
Cooper	0.1	–	0.1	Ralls	1.4	–	1.4
Dade	1.0	0.3	1.3	Randolph	91.0	22.4	113.4
Daviess	–	1.2	1.2	Ray	–	9.5	9.5
Grundy	–	1.4	1.4	St. Clair	14.7	–	14.7
Harrison	–	8.8	8.8	Schuyler	–	0.2	0.2
Henry	112.6	16.7	129.3	Sullivan	2.4	3.0	5.4
Howard	12.1	1.5	13.6	Vernon	50.5	1.2	51.7
Jasper	1.6	–	1.6	Worth	–	0.2	0.2
Johnson	28.7	3.8	32.5				
				State Totals	**633.1**	**242.0**	**875.1**

rolling, dipping, and/or eroded coal beds require sampling as close as 100 foot centers. Undeveloped reserves, when applied to coal, refers to those reserves defined by wider spaced sampling, thus having a lesser degree of certainty than that of developed reserves. The spacing differs but would be in the neighborhood of between ¼ and ½ mile centers. Potential reserves are those defined as having a limited amount of sampling information, usually projected outward from developed and undeveloped reserve areas. The limits of projection vary widely depending on the nature of the coal area, and the purpose and philosophy of the estimator. Economic parameters are also given emphasis by mining companies.

State and Federal agencies are, in general, less restrictive in developing criteria for estimating reserves. Government agencies are more likely to include marginal reserves or reserves that are likely to become economically recoverable under greatly improved economic or technologic conditions than those prevailing. It is important to include marginal resources because this demonstrates that a larger reserve exists which can be utilized when the easily mined and economically attractive reserves have been depleted.

The Division of Geology and Land Survey, Missouri Department of Natural Resources, recently completed a detailed estimate of Missouri's coal resources. This estimate was based on reserve definitions agreed to jointly by the U.S. Geological Survey and the U.S. Bureau of Mines.

It was hoped that by following these definitions an estimate could be prepared that would be consistent with Federal estimates and allow comparison with reserve estimates of other states, since most states use comparable criteria.

Only recoverable measured reserves are emphasized here. Measured reserves correspond roughly with the combined developed and undeveloped reserve categories of industry (see preceding paragraphs). Measured reserves are known to exist with a high degree of certainty and their physical parameters of seam thickness, areal extent, and overburden thickness are also known with a high degree of certainty. For this reason the state's measured reserves should be considered the basis for near- and intermediate-term development. It should be remembered, however, that it is sometimes possible to convert reserves in less well defined categories to measured reserves by additional exploration work.

Table 2 gives the remaining measured recoverable coal reserves of Missouri by county. The total measured recoverable coal reserve for Missouri is 875 million tons. Of this total, 633.1 million tons are considered a strippable reserve and 242 million tons are considered to be recoverable by shaft or drift mining only.

Assuring the availability of a sufficient coal reserve should be given top priority in the planning of any proposed major new facility utilizing Missouri coal.

Access to economically attractive "blocks" of coal land is becoming more and more difficult for new ventures as well as for established operations. Land is becoming more difficult to acquire. Some lands are unattainable at any price for reasons of family attachments, adversity to coal mining, or for tax reasons. Sometimes the tax problem can be delayed, and the land can be acquired by negotiating a land exchange.

POTENTIAL FOR INCREASING ANNUAL COAL PRODUCTION ON A SUSTAINED BASIS

An analysis of the potential for increasing annual coal production must take into account the fact that sufficient reserves must exist to assume sustained production over a long period of time. Energy-related facilities must be planned to furnish energy in the form of electricity or synthetic fuels on a continuing basis for as long as 30 years until they become obsolete and are replaced by new facilities. On the basis of 30 years sustained production, Missouri's measured recoverable coal reserve of 875 million tons would sustain an annual production of 29 million tons.

Only measured reserves are considered in making this calculation because reserves in this category are well defined and are those most likely to be developed in the coming decade. It is important to remember, however, that measured reserves constitute only a small portion of our total reserve base. After depletion of the measured reserve, advancements in mining economics and technology as well as continuing exploration will convert some of the remaining 50 billion ton resource base into a measured reserve.

By subtracting the State's current annual production of nearly 7 million tons, a production potential for future development of more than 22 million tons annually remains. As a practical matter, economic factors will determine whether or not this production capability is ultimately realized.

SECTION III

GENERAL CHARACTERISTICS OF MISSOURI COAL

Missouri coals are classified as high volatile bituminous. They are generally high in sulfur and ash content. Run-of-mine coal is often exceptionally high in ash content as compared to face samples because partings or bands of impurities are mined along with the coal. The mining of bands and partings also effectively decreases the Btu content of the run-of-mine coal as compared to face samples. Much more detailed information about the physical and chemical characteristics of Missouri coal will be required as the patterns of utilization change.

The following discussion of coal quality is based on face samples collected from operating mines throughout the years.

HEATING VALUE

Heating values for coal in the United States are expressed in British thermal units (Btu). The average Btu content for Missouri coal on an as-received basis is 11,082 Btu per pound. This value is comparable to that of Illinois, higher than Iowa, and probably somewhat lower than average values for Oklahoma and Kansas. Btu content for individual samples ranges from 9,760 Btu per pound to 12,560 Btu per pound.

SULFUR

Missouri coals are high in sulfur content. The average sulfur value for all Missouri coals is over 4.27 percent. Over half of Missouri's coal reserve contains 4 to 5 percent sulfur; one-fourth contains 3 to 4 percent; most of the remainder has a sulfur content of greater than 5 percent; and a small amount has between 2 and 3 percent sulfur.

Sulfur occurs in coal in three forms: as iron sulfide, as sulfates, and as organic sulfur. In Missouri coal, by far the greater amount occurs in combination with iron as the iron sulfide pyrite. Pyrite occurs as large nodules or concretions, as vein deposits in joints or cleat, and as finely disseminated particles. Both pyrite and sulfates can be removed from coal to some degree by conventional coal preparation techniques. However, organic sulfur occurs in chemical combination with the organic coal substance and is therefore extremely difficult to remove. The average pyritic sulfur content of Missouri coals is 2.52 percent and the average organic sulfur content is 1.66 percent. The remaining sulfur content occurs as sulfates. It is the high organic sulfur content that makes it impossible to clean Missouri coal to acceptable levels by conventional cleaning methods. Chemical methods to remove at least part of the organic sulfur as well as finely divided pyrite from coal are under development and are discussed in another section of this report.

ASH

Average ash content of Missouri coal is 11.5 percent. Ash softening temperatures are generally in the range of 1,900°F to 2,300°F. The fusion temperatures and composition of ash in Missouri coals is not seen as a deterrent to their use in most combustion or conversion processes.

TRACE AND MINOR ELEMENTS IN COAL

Coal mined in Missouri averages 61.5 percent carbon, 16.3 percent oxygen, 5.5 percent hydrogen, 4.2 percent sulfur, 1 percent nitrogen, and 11.5 percent ash. The

ash is in turn composed mainly of the oxides of silicon, iron, aluminum, calcium, magnesium, manganese, titanium, sodium, phosphorus, and potassium which typically make up between 80 to 90 percent of the total weight of the ash. The remaining fraction of ash is composed of trace amounts of many other elements. When the coal is burned, these trace elements are either concentrated in the coal ash (fly or bottom) or emitted into the atmosphere. Obviously, disposal of solid and liquid waste products of coal combustion is an environmental problem because of the possible contamination of ground water by the more soluble elements. The long term hazard of atmospheric pollution, especially in urban areas, requires further research. Elements that appear to be significantly higher than average in Missouri coal include selenium, arsenic, lead, cadmium, antimony, and zinc.

The study of trace and minor elements in Missouri coals has been underway at the State Geological Survey for nearly two years. A cooperative sampling and analysis program with the U.S. Geological Survey has yielded much valuable data and has resulted in the publication of one report: Report of Investigations No. 60, *Chemical Analysis of Selected Missouri Coals and Some Statistical Implications*.

Emphasis has been placed on the environmental implications of the occurrence of trace elements; however, the possibility of recovering certain valuable trace elements commercially will also be given consideration in future research. Proposed trace element research is given in the "Research Recommendations" section.

SECTION IV

DIRECT COMBUSTION OF MISSOURI COALS

Direct combustion is the most energy-efficient system for obtaining energy from coal.

Direct combustion of coal for home heating and industrial uses accounts for approximately 10 percent of the coal consumed within the State. Coal consumption for these purposes has remained nearly constant since 1970; however, coal consumed by electric utilities has increased over 55 percent during that time.

Coal-fired generating plants were used to generate over 85 percent of the electricity produced in Missouri in 1975, and, in so doing, consumed almost 90 percent of the state's coal consumption. Planned or proposed power plants scheduled for completion by 1985 will consume an additional 10 million tons of coal and nearly 3 million tons will be required by utilities under ESECA orders to switch from oil or gas to coal-fired boilers. The demand for coal by utilities will approach 25 million tons by 1985.

Missouri supplies less than one-third of the coal consumed by Missouri utilities. Part of this low ratio of consumption of Missouri coals has been related to the location of power plants on the Mississippi or lower Missouri Rivers which made Illinois coal readily available. More recently, the need to limit sulfur emissions has caused utilities in the western part of the state to consider low-sulfur Western coals as an alternative to Missouri coals.

LIMITATIONS AND MEANS OF SULFUR CONTROL

The high-sulfur content of Missouri coals could limit their suitability for direct combustion unless some of the sulfur is removed either before, during, or after combustion.

Removal of sulfur before combustion includes (1) the physical separation of minerals containing sulfur as a principal ingredient from the coal;(2) the chemical extraction of mineral and/or organic sulfur from the coal; and, (3) a combination of physical and chemical separation.

Coal samples have been tested for washability by the U.S. Bureau of Mines and by individual operating companies. The results of such tests, which have been reported on nine samples of coal from various beds and locations in Missouri, show that none of the nine coals tested could be upgraded sufficiently by simple physical separation to meet the EPA New Source Performance Standard of 1.2 pounds SO_2/million Btu. Considerable sulfur could be removed, however.

Coal washing and beneficiation are already being practiced at some of the operating mines in Missouri. Such preparation varies from simple washing and screening to remove coarse shale and pyrite to beneficiation by jigging, tabling, and cyclone separation.

Removal of sulfur during combustion by the addition of materials such as lime or limestone into the coal combustion zone in a fluid bed chamber is receiving national interest. In this process (fluidized-bed combustion), the sulfur compounds evolved during the coal combustion are contacted immediately with lime or other sulfur-gathering particles to form sulfur

compounds which are then removed with the ash. Such a system would not be adaptable for retrofitting to existing systems, but should be considered in planning new facilities.

Flue gas desulfurization methods have been developed for removing sulfur from combustion gases by wet scrubbing. Lime and limestone scrubbing are wet-scrubbing methods which produce a sulfur-bearing product for disposal. Over 25 limestone scrubbing systems have been installed around the country and Kansas City Power and Light operates a limestone scrubber at its La Cygne station. The amount of finely-ground lime or limestone required for this process and the large amount of solid waste to dispose of are problems to consider when using lime or limestone scrubbing. Post-combustion processes can be added to existing systems.

Approximately 90 percent of the sulfur entering a scrubber can be removed by scrubbing with a lime or limestone slurry. The higher the sulfur content of the coal, the more lime or limestone will be needed to remove the SO_2 formed. Removal of a portion of the sulfur by washing or by other mineral beneficiation means prior to combustion could minimize the amount of scrubbing required to meet or exceed the established Federal New Source Performance Standards. At the same time, scrubbing costs and the amount of ash and sludge for disposal would also be reduced.

There are several other post-combustion processes such as the Wellman Process, the Bureau of Mines Citrate Process, and the IFP Ammonical Brine Process which remove the sulfur oxides from the gas and recover an elemental sulfur. The experience is presently limited on large-scale boilers burning coal with high sulfur content. The reliability and operating costs of such units need improvement.

Chemical methods of removing sulfur from coal have been achieved in the laboratory but have not yet been successfully demonstrated on a large scale either technically or economically.

UTILIZING MISSOURI COALS IN DIRECT COMBUSTION

Missouri coals cannot be burned in new installations without sulfur reduction by either beneficiation, leaching, fluid bed combustion with limestone, stack gas cleaning, or a combination of methods.

Increased use of Missouri coals in either new or existing facilities will be strongly dependent on the ability of the coal producer or coal consumer to meet the sulfur requirements. Research is therefore needed to determine the feasibility of upgrading Missouri coals.

Additional washability studies should be made to establish the degree of sulfur removal obtainable by heavy media separation, jigging, tabling, cycloning, or other gravity separation methods.

Mineral beneficiation research is needed to establish whether known separation processes can be applied to fine-ground Missouri coal to further improve sulfur elimination. Some processes which should be considered are froth flotation, dry magnetic separation, dry chemical processing to magnetize pyrite and ash for magnetic separation, and wet high-intensity magnetic separation. Results of such research will help establish attainable sulfur reduction limits.

Cost evaluation studies pointing out the potential benefit or lack of benefit to be derived from the desulfurization of

Missouri coals by combined beneficiation/ flue gas cleaning processes would be beneficial to the Missouri coal industry.

Research efforts relating to chemical cleaning or desulfurization of coal should be followed and when practical methods are devised, their application to Missouri coals should be considered.

A recently organized university coal research group may be in a position to aid in the solution of some of the problems relating to the utilization of Missouri coal. This group, the Interior Province Coal Laboratory application consortium consists of Iowa State University, Southern Illinois University, the University of Missouri at Columbia, and the University of Missouri at Rolla.

TRANSPORTATION

Most of the coal that is mined in Missouri is consumed by mine-mouth steam generating plants with short off-road truck hauls or short rail hauls. An increasing amount, however, is being shipped by rail or truck to independent utility and industrial customers. Coal consumed, but not mined in Missouri, is transported by rail, barge, or rail-barge combination. Approximately 70 percent of the coal consumed in Missouri is mined in other states.

Currently, approximately 14 million tons of the coal consumed in Missouri is shipped by rail. An increase in rail shipments of 1,600,000 tons of coal is projected for 1985. Current barge tonnage is 5,500,000 and truck deliveries account for 3,814,000 tons per year. Most of the truck deliveries are accounted for by short mine-mouth hauls. An increase in truck haulage of 2,500,000 tons is projected for 1985.

Because availability of rail transportation would tend to make some undeveloped Missouri coal deposits economically competitive in the future, an effort should be made to preserve rail-lines which serve the state's coal fields, where practical. The Missouri Department of Natural Resources should cooperate with the Missouri Department of Transportation in identifying rail-lines that should be preserved.

Proposed future coal transportation facilities include conveyor belt haulage and two coal handling facilities at St. Louis.

Increased industrial consumption would result in a sharp icrease in truck transportation in Missouri. Mine-mouth generating plants minimize coal transportation requirements.

Slurry pipeline transport is also a possibility.

SECTION V
USE OF MISSOURI COAL THROUGH GASIFICATION OR OTHER CONVERSION PROCESSES

PROMISING CONVERSION PROCESSES

Missouri coal deposits average between 4 and 5 percent sulfur. This is far above the levels permitted by Federal regulations for direct combustion. Washing can remove some sulfur and emission controls (stack scrubbing) may permit facilities burning Missouri coal to meet the New Source Performance Standard of 1.2 pounds SO_2/million Btu. Conversion of Missouri coal to low sulfur fuels is another way to control the sulfur emissions problem.

As the demand for natural gas and petroleum products increases and as reserves are more difficult to find, conversion of coal to synthetic petroleum and natural gas should take place on an increasingly larger scale. Some of the more promising conversion processes include (1) high Btu or pipeline quality gas, (2) solvent refined coal, (3) low Btu and synthesis gas, and (4) liquid petroleum substitutes. In-situ gasification of coal or possibly the tapping of methane from deeply buried coal seams are other long term possibilities.

LOW TO MEDIUM BTU GAS

Conversion of coal to gas is not a new concept. The first manufactured gas was obtained from the simple coking of coal. This type of gas was used in Britain early in the 19th Century. The water gas process of gasifying red hot coke with steam to form carbon monoxide and hydrogen was also developed early in the 19th Century as was the producer gas process. The producer gas process consists of burning coal with insufficient air for complete combustion. The resultant gas consists primarily of hydrogen and carbon monoxide and has a heat content of approximately 130 Btu per cubic foot. Air blown producers have provided fuel as town gas and industrial gas since 1836. In the middle 1920's, 12,000 gas producers were operating in the United States and converting 25 million tons of coal per year to fuel gases. The low Btu content is due to the dilution with nitrogen from air. By using oxygen, an intermediate Btu gas (350 Btu per cubic foot) consisting of hydrogen and carbon monoxide is produced. This gas, known as synthesis gas, can be burned as a fuel; converted to methane, methanol, or gasoline; or it can be used as a feedstock for producing ammonia.

Producer gas was formerly used for boiler heating, ore roasting, and lime and cement manufacturing. Enthusiasm was widespread in the industry and production of gas at large central plants at the mines with gas distribution through pipe systems was proposed.

Such gas, produced by one or more processes, has been considered as a substitute for natural gas and fuel oil in refractory clay product plants in Missouri. It could serve as fuel in industrial parks or complexes as well as in municipalities. Chemical plant feedstock and utility plant peaking requirements are other possible uses. Missouri coal could fuel a number of these plants should economic factors make it feasible in time.

The U.S. Bureau of Mines, at its Twin Cities Metallurgy Research Center, has a

cooperative program with DOE and industry for utilizing low Btu gas for pelletizing in a grate kiln system. The project is also considering the economics of on-site and centrally located coal gasification plants; retrofit requirements; and the economics of conversion of shaft furnace, grate kiln, and travelling grate systems to accept low Btu gas. This program is of interest to Missouri since two companies are presently producing nearly 2 million tons of iron ore pellets in the state by using oil, propane, or natural gas fuels for firing the pellets.

Significant effort has been expended in developing coal gasification and related facilities in Missouri by two "joint venture" groups. A proposed facility at Palmyra, Mo. would gasify some 5 million tons of coal per year to produce low Btu gas that, in turn, would fuel gas turbine generating units and supply feedstock (hydrogen source) for ammonia production. Planning for the Palmyra plant has been underway since 1974. The principal interests are Associated Electric Cooperatives and Farmland Industries. At last report, however, this project had been placed in a "holding" status by management.

A second projected gasification project is being developed by the Consumer Energy Corporation. The project, initiated by FEA Region VII officials at Kansas City, proposes the gasification of coal to fuel combined cycle (gas turbine/steam) generating plants with prioritized (seasonal) allocations of gas to industrial methanation plants. Preliminary plans for low Btu gasification plants elsewhere are known but have not been officially announced.

Two of these would produce gas for peaking generator fuel and one would supply essential gas fuel to a major industry, but their current status is unknown.

Applications of low Btu gasifiers are being rapidly developed. Six groups were recently selected to negotiate costs (DOE would share up to 50 percent) and contracts for the design, construction, and operation of low Btu (150 to 300 Btu per cubic foot) coal gasifiers. Results of some of these projects would have application in Missouri (table 3).

Other developments in low Btu gasification include the following: Allis Chalmers, in cooperation with 11 electric utilities, is completing engineering work on a low Btu gasification process identified as the "Kilngas" process; and Westinghouse received a $260,000 contract from the Commonwealth of Kentucky for direct reduction of iron ore using gas from high sulfur coal.

HIGH BTU (PIPELINE QUALITY GAS)

To be suitable for transporting long distances by pipeline, synthesis gas must be converted to methane which has a Btu content of approximately 1,000 Btu per cubic foot. Because of the additional cost of methanation and the high demand for pipeline gas, economy of scale is resorted to in planning high Btu gasification plants. For proposed pipeline gasification plants, the standard figure used for planning is 250 million cubic feet per day. A plant of this size would consume 13,000 tons of coal per day or 4.7 million tons per year.

There is little doubt that the first large scale second generation coal conversion plants will be built in states having large coal reserves which occur in thick, easily mined beds. In Missouri and bordering states, it would be difficult to acquire contiguous, uncommitted reserves large enough to support such a large plant for its life of 20 to 30 years.

Table 3

PROPOSED LOW BTU COAL GASIFIER CONTRACTS
(costs to be shared by DOE)

Group or Agency	Application
Glen Gery Brick Company, York, Penn. with *Aerotherm Division, Acurex Corp. Mountain View, Calif.	Brick Kiln
General Refractories Co. Hitchins, Ky.	Refractory Kiln
Irvin Industrial Development, Inc. Georgetown, Ky.	Industrial Park (conditional)
Land O' Lakes, Inc. Minneapolis, Minn.	Space Heating & Drying
Pike County Kentucky	Heating/Cooling (conditional)
*University of Minnesota Minneapolis, Minn.	Space Heating

*Recently approved for funding

Production of high Btu gas must be considered a long-term matter in Missouri and adjoining states. For such a plant to become a reality, there must be a demonstration of the existence of an uncommitted, economically recoverable coal reseve of sufficient size. However, scale-down of commercial high Btu gasification plants to between 50 and 100 million cubic feet per day would make high Btu gasification a possible alternative use for Missouri coal.

IN-SITU GASIFICATION

In-situ gasification offers the prospect of recovering a clean gas fuel from seams of high sulfur coal that are too thin or too deep to mine. Areas have been outlined in Missouri which contain considerable coal tonnages in multiple thin seams at depths ranging from 150 to 1,000 feet. The Division of Geology and Land Survey's Goshen drillhole is illustrative. This hole contains 202.5 inches (16.9 feet) of coal in nine beds ranging from 12.5 inches to 48 inches in thickness.

Successful application of in-situ gasification technology to such areas would give Missouri a better chance of producing a greater share of its domestic energy needs. In addition, technologic advancements developed in an experimental facility in Missouri would be applicable to other states in the Western Interior Coal Region, thereby opening up a significant national energy resource.

Recovery of energy on a commercial scale by in-situ gasification must be considered a long term prospect. However, experimental facilities are presently operating in Wyoming and West Virginia. Missouri would be ideal for a third experimental in-situ gasification facility to determine the feasibility of this method in the Western Interior Coal Region.

RECOVERY OF METHANE FROM DEEP COAL SEAMS

Coal seams contain varying amounts of methane that are released when the coal seam is opened by mining or drilling. This gas presents a hazard in underground mining, and the current practice is to "bleed off" the methane in advance of mining by drilling. The methane thus recovered is delivered to nearby towns for consumption. Because it is possible to recover methane from deeply buried coal seams that may never be mined, a large potential supply of gas is available in Missouri and other coal-bearing states. However, the technical and economic practicality of recovering methane by this method remains to be demonstrated.

SOLVENT REFINED COAL

Solvent coal refining appears to be ideally suited to the production of a clean-burning, low-sulfur fuel from high sulfur Missouri coals. This process produces a solid fuel with a heating value of 16,000 Btu per pound and less than 0.1 percent ash and less than 0.8 percent sulfur.

Sulfur and ash are removed from pulverized coal by using organic solvents. The clean liquid product is very versatile and can be maintained as a liquid at high temperatures. When cooled, it solidifies and can be formed into solid particles called prills. The fuel may be used for direct firing, either as a liquid or as a solid, and is suitable for boilers and peaking units. Specific Missouri coals should be evaluated for suitability as even our poorest coals may be suitable.

LIQUEFACTION

Coal can be converted to liquid fuel by hydrogenation. Several processes are being developed and plans have been announced to build coal liquefaction plants. At this stage in the development of coal liquefaction processes, it appears that the emphasis on economy of scale would require such large coal reserve tonnages that they would be difficult to acquire in Missouri.

One particular avenue of research that is of interest because of its application to liquefaction of thin coal seams is described below.

Preliminary research by the Mining, Petroleum and Geological Engineering Department at the University of Missouri—Rolla indicates that in-situ liquefaction may be an effective and economical procedure for recovering the energy content of thin coal seams, possibly as thin as six inches. By contrast, in-situ gasification studies indicate that there is a minimum seam thickness that can be efficiently recovered by this process. The probable minimum seam thickness for in-situ gasification is in the range of 18 inches.

METHANOL

Methanol, produced from synthesis gas (carbon monoxide and hydrogen), is a clean-burning fuel that has been used successfully in internal combustion engines and in fuel cells. It is being seriously considered as a substitute for liquefied natural gas. Methanol can be produced from feed from low Btu gasification plants.

SECTION VI

EFFECTS OF ENVIRONMENTAL CONSIDERATIONS ON FUTURE USE OF MISSOURI COAL

AIR QUALITY

Air quality is an important factor to be considered in the prudent future development of new and increased uses of Missouri coal. In recent years, probably the two most important subjects of interest in government control have been the environment and the energy crisis. If proper planning and consideration are used, more Missouri coal may be utilized in an environmentally acceptable manner. A number of environmental regulations and laws have already been developed that primarily control existing air pollution sources and are aimed at achieving good air quality throughout the country. Also there are regulations that are aimed at controlling emissions from new sources in order to protect or maintain air quality. New environmental controls being considered include the prevention of significant deterioration to keep clean areas from being polluted by future growth. Along with significant Federal air deterioration legislation, legislation on siting large energy sources is being proposed on the state level.

Air pollution control regulations being enforced in Missouri are not preventing the use of Missouri coal in existing sources. However, the adoption of Federal New Source Performance Standards in 1975 will affect the use of Missouri coal in new large facilities to be constructed.

Non-deterioration amendments to the Clean Air Act were seriously considered by Congress in 1976. If such legislation becomes law, it will require large new emission sources to be evaluated for effects on existing air quality and it could prevent concentration of large sources in clean areas of the state. This could affect the planning of future energy centers in Missouri.

MINED LAND RECLAMATION

Because of Federal legislation on the control of surface mining and the regulation of reclamation, it is important to assess research needs for improving the effectiveness and efficiency of reclamation practices. Reclamation costs in states with regulations comparable to those now being implemented in Missouri reportedly range from $4,000 to $6,000 per acre. Based on costs in states with similar topography in coal producing regions, reasonable costs in Missouri (at today's labor and equipment prices) would be in the $4,000 per acre range. For 3-foot coal seams this would add about one dollar to the production cost per ton of coal, and for thinner seams, this cost would be proportionately higher. Reclamation costs for prime farm land may be much higher. This clearly suggests that new reclamation technology will be necessary if Missouri coals are to be produced competitively with coals from the thicker seams of Illinois and Kentucky. Reclamation costs on a per-acre basis will likely be somewhat less in Missouri than in western states because of climate and other factors. The impact of reclamation costs on a tonnage basis, however, will be relatively high because of thin coal seams. This is likely to be an important factor in the economics of coal production in Missouri.

Federal legislation contains provisions

for a trust fund, the Abandoned Mine Reclamation Fund, that is derived from the sale, lease, or rental of mine lands, user charges, and reclamation fees. The fund, administered by the Secretary of Interior in cooperation with the Secretary of Agriculture, supports state programs for reclaiming land mined before the legislation was enacted. The Division of Geology and Land Survey, in cooperation with the Land Reclamation Commission, is currently directing an inventory of surface mined land in Missouri. This study is needed to insure Missouri's participation in these Federal funds. It is essentially limited to determining the areal extent of disturbed lands though and will have to be expanded to include a detailed plan and cost estimate for reclaiming each abandoned mine site. Extensive field studies will be required to determine the reclamation project that would be best suited for each site. To insure cost effectiveness, these projects should be supported by appropriate research and development activities to improve reclamation methods so the land can be restored for the best ultimate use at minimum cost. Such research and development should be coordinated with the mining industry's studies of reclamation of lands disturbed in on-going mining operations.

WATER REQUIREMENTS

Water is a significant requirement during all phases of coal utilization from mining through various uses to the reclamation of the land disturbed by mining. The availability of water in many cases is a greater limiting factor than the availability of coal, especially in water-short Western states where the annual rainfall is appreciably less than in Missouri. The average water needs for a coal-fired generating plant, for example, are 25,000 acre-feet per 1,000 megawatts of capacity.

Estimates of water needs for the various methods of gasification and liquefaction of coal vary widely because the technology is untested in commercial-scale operations. However, water requirements are likely to be high. A proposed demonstration liquefaction plant at Morgantown, West Virginia would process 6,000 tons of coal per day and use 4,000 gallons of water per minute to produce 12,000 barrels of synthetic fuel per day.

Missouri's location in the Midwest where average annual rainfall is about 40 inches makes water availability a much less limiting factor in planning for coal resource utilization. This factor has led to consideration of shipping Western coal to Missouri for conversion to synthetic fuels.

SECTION VII

LOOKING TO THE FUTURE

THE IMMEDIATE FUTURE OF MISSOURI COAL

Ninety percent or more of Missouri's coal production is used by electric utilities for generating electricity, mostly in northern and western Missouri and in southern Iowa. Coal-fired electric generating capacity is scheduled to increase substantially in this marketing area during the coming decade. However, Missouri coal is too high in sulfur content to meet New Source Air Quality standards without some type of desulfurization. In each proposed new coal fired generating facility, Missouri coal must compete with low-sulfur Western coal. The cost of sulfur removal from Missouri coal must be weighed against the transportation cost of Western coal and the fuel source chosen accordingly.

New Source Performance Standards, recently announced by the federal EPA, may improve the position of Missouri coal in the utilities market. The NSPS would essentially require scrubbers on all coal-fired units, regardless of the initial sulfur content of the coal.

There is some potential for increased use of Missouri coal in existing generating plants, both in replacing out-of-state sources and in supplying utilities under ESECA orders to convert to coal. If coal producers can demonstrate that Missouri coal can be delivered to existing facilities at competitive prices, parts of these markets can be captured. To meet the required quality standards regarding Btu, sulfur content, and ash, the mine-run product will need to be upgraded by beneficiation.

There is potential for increased use of Missouri coal for industrial use. Some industries may be able to use coal for direct firing, but conversion of coal to low or intermediate Btu gas may be more practical in other instances. Industries that rely heavily on natural gas may be forced to turn to coal when natural gas is no longer available. The potential for the industrial use of Missouri coal is discussed in more detail elsewhere in this report.

Institutions and private individuals constitute markets for Missouri coal. Colleges, universities, primary and secondary schools, and hospitals consume coal for space heating. Missouri coal can meet these needs, particularly if the mine-run product is upgraded by beneficiation. Many private residences in rural areas use coal for space heating. Although this market is small in terms of today's huge potential markets, it is nonetheless important to those individuals who depend upon coal as a fuel source. This modest market may increase substantially if the price of other fuels continues to rise. There are many thin, near surface coal seams in Missouri that could supply this type of local market.

PROPOSED PROJECTS THAT MAY EXPAND UTILIZATION OF COAL IN MISSOURI

Table 4 lists major proposed utilization and synthetic fuels plants for Missouri. Three coal-fired units will use Wyoming coal and one will use Illinois coal. Associated Electric's Thomas Hill No. 3 unit will use 3.8 million tons per year of Missouri coal. Springfield City Utilities' Southwest No. 2 may use Missouri coal. Four new nuclear plants which will supply power to Missouri utilities are planned, but only one will be built in Missouri.

Table 4

MAJOR EXISTING AND PROPOSED INSTALLATIONS THAT REFLECT CHANGING USE PATTERNS OF MISSOURI COAL

Planned Coal-fired Steam Plants or New Units at Existing Steam Plants

Utility	Unit	MW	On-line	Fuel	Fuel Source
	Thomas Hill #3	600	1981	Coal	Missouri
Kansas City Power and Light	Iatan #1	726	1980	Coal	Wyoming
	Iatan #2	726	1985	Coal	Wyoming
City of Springfield	Southwest #2	209	1986	Coal	––
Sikeston Municipal	Sikeston	235	1980	Coal	Illinois
Empire District Electric	Asbury #3	300	1985	––	Wyoming
City of Independence	Blue Valley #4	150	1983	Coal	––

Nuclear Plants

Utility	Unit	MW	On-line	Fuel	Fuel Source
Union Electric	Callaway #1	1,150	1983	––	––
Associated Electric	Black Fox #1 (Okla.)	––	1983	––	––
Associated Electric	Black Fox #2 (Okla.)	––	1985	––	––

Gasification Plants

Proposed Coal to Low to Medium Btu Gas Generation Facilities

Group	Unit	Type of Plant
Missouri Energy Center	Palmyra –	Gas Turbine and Chemical Feedstock (on hold)
Consumer Energy Corporation	Reger –	Combined Cycle & Industrial Fuel
Consumer Energy Corporation	Yates –	Combined Cycle

Three plants to convert Missouri coal to low intermediate Btu gas or other products are under consideration, however, the proposed Palmyra plant is now on hold.

IMMEDIATE RESEARCH REQUIREMENTS

The most pressing immediate research requirement is the need for a better assessment of the availability of uncommitted economically recoverable coal reserves. Before any large scale mining projects can be contemplated, the existence of sizable blocks of uncommitted economically recoverable reserves must be demonstrated. Work on this project has already begun, but much remains to be done. Coal producers are cooperating in this task. In addition, detailed mapping and reserve evaluation of the important Bevier coal field in northern Missouri is being carried out by the Division of Geology and Land Survey.

There is also an immediate need for evaluation of the potential for upgrading Missouri coal by beneficiation to meet the standards required in existing facilities that may switch to coal. There is also some potential for reducing stack desulfurization costs by a combination coal beneficiation stack-scrubbing system.

Production cost estimates on surface mining and cost data on desulfurization should be determined. The potential for and probable costs of underground coal mining and coal transportation in Missouri should also be determined. Realistic economic data are needed to aid in the realistic evaluation of the potential for coal conversion projects. Other near-term research needs include determination of the potential for low to intermediate Btu gasification, fluidized bed combustion, and production of solvent refined coal. Environmental studies of the impact of mining and trace element studies are also relevant. All of these subjects are covered in greater detail elsewhere in this report.

THE LONG-RANGE FUTURE OF MISSOURI COAL

Coal is a very versatile substance and has many potential uses. As the more easily mined reserves are consumed, many deposits now considered marginal will eventually be mined. The development of advanced mining technology and in-situ conversion processes will also ultimately aid in the recovery of reserves that are now considered economically marginal. Missouri's coal resource base will continue to be a sought after natural resource for many years, both for energy production and as a source of petrochemical substitutes in the future.

LONG-RANGE RESEARCH NEEDS

Long-range research needs include assessment of the potential for in-situ gasification, production of methane from deeply buried coal seams, high Btu pipeline quality gas, and petroleum substitutes from coal. The potential for underground mining should be considered on a long term basis since underground mining would be necessary to supplement surface mining if large scale coal conversion should become a reality in Missouri.

CONCLUSION

The road to increased coal production in Missouri may be a difficult one. High sulfur content, high production costs, and difficulty in acquiring reserves are major hurdles. Competition from Western states will be stiff. However, the Western Interior Coal Region of Missouri, Iowa, Kansas, Oklahoma, and Arkansas remains a substantial potential source of energy for our nation. From this standpoint alone, research and development should be encouraged.

Whether Missouri and other states in the Western Interior Region will ever realize their coal production potential is likely to hinge on decisions made at the national level. If the United States continues to rely heavily on imported oil rather than on its own fuel resources, then U.S. coal production will increase only moderately and competition from other coal producing states will depress Missouri's coal production.

However, if the United States decides to rely on domestic fuels, then U.S. coal production will increase dramatically and production from all areas, including Missouri, will be needed.

President Carter's recent energy message, emphasizing the development of U.S. coal resources as an answer to the Nation's energy problems brightens the prospects for coal development in Missouri.